How Is My Wind Farm Performing?

Claudia Puyals [1], Jesica Piñón [1], Sandra Florentino [2], Itamar Lessa [3],José Vidal [1]

1 AWS Truepower, SLU

Baldiri Reixac, 10. 08028 Barcelona, Spain

2 AWS Truepower do Brasil LTDA

Voluntários da Pátria 45, Sala 1206, 22270-900 RJ, Brazil

3 Casa dos Ventos Energias Renováveis S.A.

Av. Brigadeiro Faria Lima, 2.055 12°andar - Pinheiros

01452-001 São Paulo,SP

cpuyals@awstruepower.com, jpinon@awstruepower.com, sflorentino@awstruepower.com, itamar.lessa@casadosventos.com.br, jvidal@awstruepower.com

Wind farm SCADA data holds an enormous potential for plant performance improvement and should be an essential tool for Operation and Maintenance (O&M). The method currently used to perform this kind of analysis by control centers, specialized software applications or external consultants, is a more or less sophisticated data mining of the huge amount of information contained in SCADA, looking for actual or potential failure points, and synthesizing the results in a list of Key Performance Indicators (KPI). If done in the right way, this analysis can lead to important benefits through the improvement of turbines performance, as well as costs reductions through optimization of the O&M strategy and extension of components lifetime.

However, the SCADA data analysis, performed as just described, doesn’t answer the fundamental questions of the investor: how is my wind farm performing compared to the budget? And if it’s not performing well, can I do something to solve it? In this paper the authors show how to answer these questions by combining preconstruction estimates, a consistent long-term reference data and SCADA data analysis.

Keywords: *Plant performance, SCADA.*

INTRODUCTION

Wind farm SCADA contains a big amount of high-valuable information that in most cases is not exploited at its maximum level. In general, only a small fraction of SCADA data is analyzed, even for those wind farms integrated in control centers. Furthermore, the analysis is frequently only superficial.

The huge amount of different information contained in SCADA makes the analysis a complex task. Technical knowledge of wind turbines, combined with experience in analysis techniques of large amounts of data are mandatory requirements to exploit the entire potential of this data and obtain reliable and useful results. Usually, such specialized analysis keeps this fundamental work too far from the investor community. It can be difficult for them to understand and recognize the deserved value of the operational data analysis work.

One of the characteristics of the current methods is that the analysts are usually searching something in the dark: there's no previous information about how good or bad is the wind farm performing, other than the feeling of one or several stakeholders, which can be in the end based only in an over-optimistic preconstruction estimate or an extended period of below-than-normal wind. No matter what is really happening or what extra information do you have; in the end, all the data is explored looking for something going wrong in the wind turbines. And if the analysis doesn't find anything, you still don't know if everything is fine, or if you didn't the proper search. For this reason, big data techniques are being incorporated in SCADA data analysis with great success, as they allow the user to "blindly" find patterns.

Generally speaking, in the way the analysis is normally performed, the analyst is not able to answer the question from the investor, and is only tangentially working in answering it. However, if the whole analysis switches the focus to the answer of the question, the analyst automatically will know what is looking for in the SCADA data and what he should expect to find. The key point is to find or build a suitable benchmark that allows the analyst to say for every given period if the wind farm is under or over-performing compared with the preconstruction estimates.

Once the reference value is well established, its difference with the actual value will be the result of inadequate availability assumptions, underperformance issues, or wrong preconstruction estimates. The first two elements can be quantitatively assessed through a focused analysis of the SCADA data. The procedure might seem similar, but the analyst knows beforehand how large is the problem he is looking for or if apparently there's no problem at all, so he can objectively prioritize how deep to go in the analysis. Finally, the conclusion will be if the gap can be corrected through specific actions, or not.

MONTHLY ENERGY PRODUCTION BENCHMARK: POTENTIAL ENERGY

The challenge is to have a reliable parameter to which we can compare the actual energy production of the wind farm. The comparison should easily explain if the performance is according to what was expected. One possible benchmark value is what is called potential energy, an abstract concept that can be defined as the energy produced by the wind farm with no underperformance issues and with 100% availability. It is worth to note that the potential energy reminds but is not exactly the same as the *Potential Production* defined by the IEC in [1]

The potential energy can be calculated with a reasonable effort in a monthly basis. Using the preconstruction measurements and a suitable layout design and energy capture software, like Openwind®, the user can extract a time series of estimated energy production of the wind farm and apply the standard losses assumptions used in the preconstruction estimates, except the ones related with availability, which should be considered zero for this purpose. Ten-minute production data is then synthesized in monthly values and correlated with a consistent long-term time series, as the ones offered by global reanalysis models. In our case we choose CFSv2 because the preconstruction measurements started after 2010 and the model is updated consistently just some days after the end of the month.

From the relations found in the previous step, we can do a reasonable estimation of the ideal monthly production of the wind farm using the reanalysis wind speed as predictor, and compare with the estimated long-term energy (the monthly P50), and with the actual energy production at revenue meter. The former comparison tells us if the wind of that month has been below or above the normal values, or at least the values considered as long-term average in the preconstruction estimates. In the latter comparison, the gap between the potential and the actual energy is, if all the other assumptions are correct, the energy lost due to unavailability and/or underperformance of the wind turbines. An example of these comparisons is plotted in Figure 1. SCADA data should help us in the evaluation of the contribution of each element.

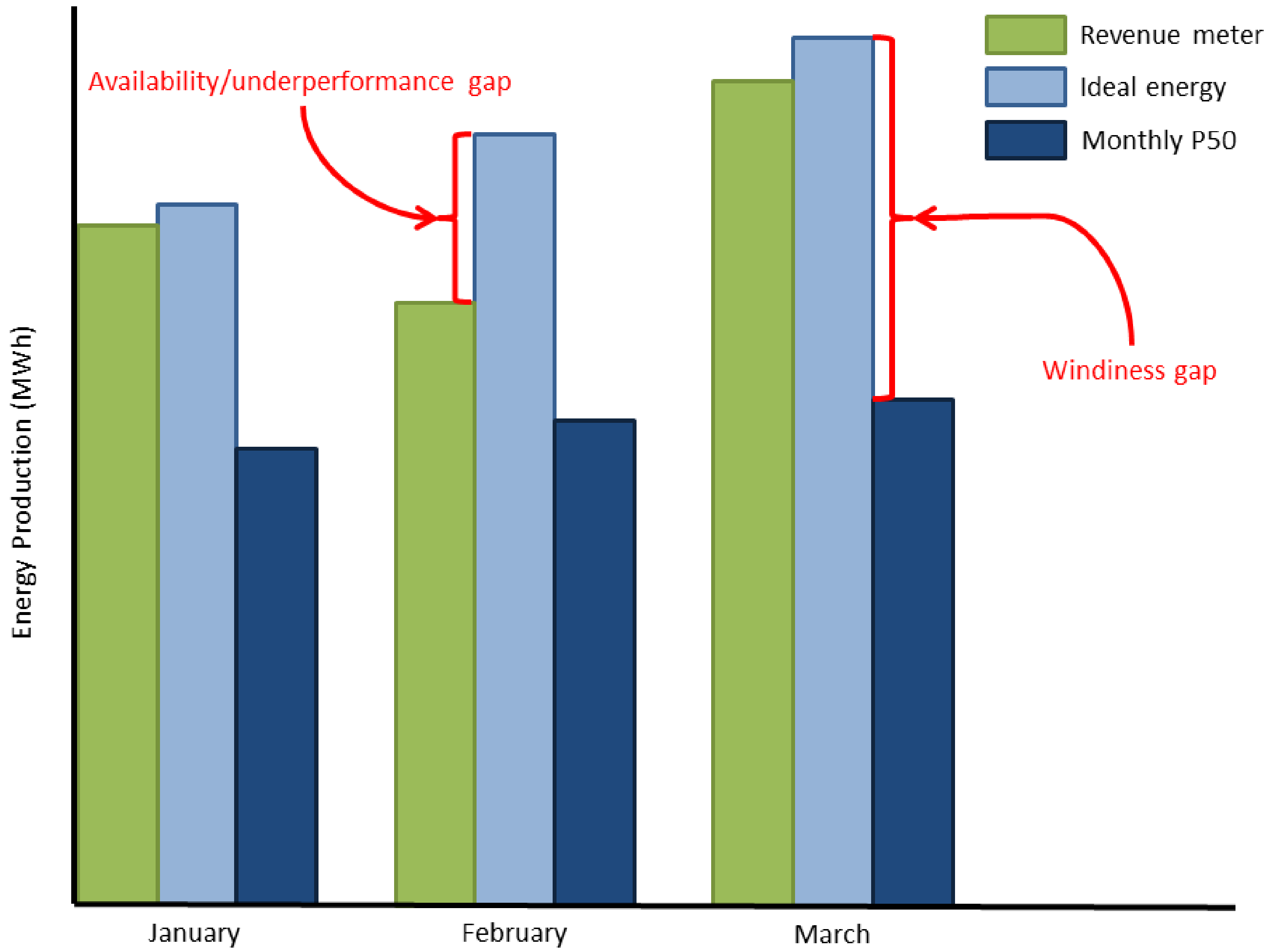

Figure 1 – Schematic monthly comparison of the actual energy generation, the expected ideal energy for that particular month and the P50 estimation for one wind farm.

ENERGY-BASED AVAILABILITY LOSS

For the estimation of the availability loss, is useful to focus the analysis in the event log analysis of the SCADA, and not in the full ten-minute data. This log contains the alarms and other events registered and can be treated statistically in order to obtain relevant information of the general performance of the wind farm, a first impression of its health, but also a register of the periods where the turbines are stopped although there are working wind conditions.

The data should be properly classified and filtered. First, alarms are characterized depending on their action, is different if they actually stop the turbine, de-rate it or if the event is only a warning message. Second, the overlapped events are filtered out, adapting the start times of partially overlapped alarms.

From a performance perspective, the most important variables are total downtime and lost energy, and this is the primary goal of this part of the analysis. The obtained values of availability loss can be compared with the preconstruction estimates, and evaluate if the assumptions were too optimistic/pessimistic, or if the wind farms is experiencing specific issues with the O&M.

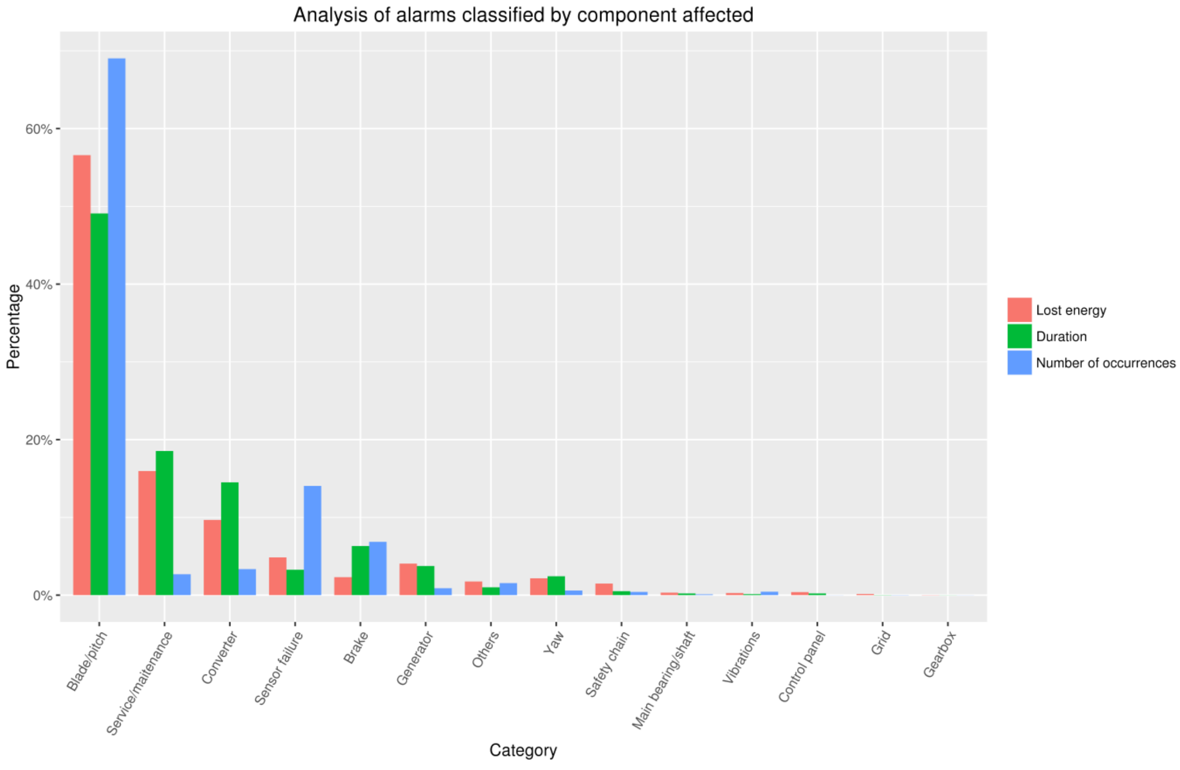

Figure 2 – Percentages of lost energy, downtime and number of occurrences of alarms per component.

Plotting the total downtime and the lost energy classified by category can provide a deeper insight into the wind farm health. Classification categories can be very varied and customized, but one of the most used schemes is by turbine component, as shown in Figure 2. In this way, it is very easy to identify which components are suffering more in a wind farm or cluster of turbines, compare between manufacturer or turbine models, etc. This information can be used to design a specific maintenance strategy and also for End of Warranty (EoW) inspections, in order to focus them in the most problematic components and turbines. Applying this condition-based maintenance, O&M costs can be significantly reduced.

UNDERPERFORMANCE ANALYSIS: OUTLIER DETECTION AND POWER CURVES

A wide range of variables is contained in 10-minute SCADA data, therefore the first step would be to determine which variables are really interesting for the purpose of evaluation of lost energy, and in which manner we want to analyze them. As with the events log data, it is convenient to apply some filtering and processing; the most important in our case is to filter out all those 10-minute registers which have an stopping alarm associated, that is to say, flag all 10-minute registers where the turbine has not been operating during 600 seconds, because this lost energy should be accounted as unavailability and not as an underperformance issue.

One of the most effective ways to analyze 10-minute SCADA data is through outlier detection. The goal is to identify turbines with abnormal behavior in one of several aspects, where the “normality” is defined by the comparison with the turbines of the same windfarm or cluster experiencing comparable conditions. This methodology can be applied to almost all variables contained in the SCADA data.

Outliers analysis applied to power curves allow the identification of practically any underperformance issue. Moreover, the method can be complemented with different types of outliers. For instance, it is possible to calculate outliers of power curve by wind direction sectors, compared with manufacturer or reference power curve of the site, or with actual power curve of the rest of turbines. An example is shown in Figure 3; in this case a broken nacelle wind vane caused a yaw misalignment and an important underperformance of the turbine.

The lost energy due to underperformance can be estimated as the difference between the actual energy as measured by the system for every time step, and the theoretical energy production following the power curve. This can be tricky when the problem is generated by a malfunctioning nacelle anemometer; in this case we should use another references as neighbor turbines, or any other proxy.

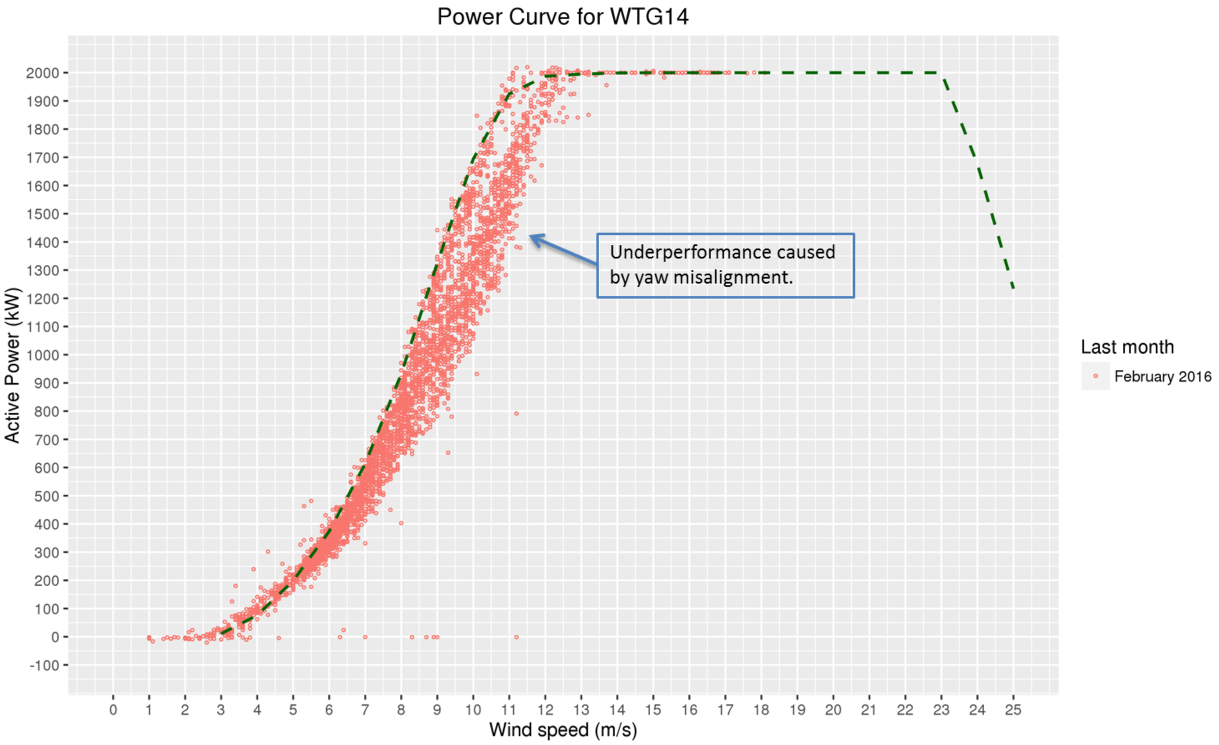

Figure 3 - Abnormal power curve detected by outlier detection methodology.

Once outliers are detected, it can also be programmed an algorithm to determine the root cause of the observed anomaly and the specific corrective actions to address the problem. Typical issues that can be identified with analysis of power curves are pitch angles and yaw position misalignments, wind sensors failures, curtailments and de-ratings not expected, dirt and ice on blades, problems in generator, wrong software configurations, opened blade tips in passive stall turbines, etc.

The analysis of the temperatures of main components is a paramount element to detect future damages in early stages. We can use temperatures from any sensor in the turbine, but some of them are key ones; these are generator bearings and windings, gearbox bearings and oil, main bearing and transformer. The best way to analyze temperatures is by periodically checking their trends. However, if we want to check temperature trends from several variables and for lots of turbines, the most effective way is the periodical search of outliers, which will identify those turbine components that are working at higher temperature ranges compared with others with similar characteristics. By addressing the issues detected with this kind of analysis, it is possible to reduce maintenance costs and increase components lifetime.

Other variables contained in SCADA can definitely be a great indicator of some specific problems. For instance, blade pitch angles outliers can be used to detect pitch misalignments that are not reaching enough level for alarm activation, but are producing underperformance. The same happens with yaw misalignment, bad-compensated reactive power or wrong generator rpms due to incorrect software parameters. Data from meteorological towers or from the revenue meter can also be integrated in these analyses. Using this external data, several additional independent performance indicators can be calculated, complementing the analysis and providing a deeper insight into the windfarm behavior.

CONCLUSIONS

This paper shows how the SCADA data can be analyzed from a different point of view if the focus switches from the operator to the investor perspective. The establishment of a synthetic monthly reference production value for each wind farm, which can be compared directly with the actual production, allows the analyst to affirm if the plant is running according to preconstruction estimates, or if is experiencing issues that should be diagnosed through the deep analysis of the SCADA data.

NOMENCLATURE

IEC: Acronym of the International Electrotechnical Commission, an international standards organization dealing with electrical, electronic and related technologies.

KPI: Acronym of Key Performance Indicator, a performance measurement index.

SCADA: Acronym of Supervisory Control And Data Acquisition, is a system for remote monitoring, control and acquisition of data that operates with coded signals over communication channels.

REFERENCES

[1] International Electrotechnical Commission IEC, *IEC 61400-26-2: Production based availability for wind turbine generating systems.*

BIOGRAPHIES

Claudia Puyals – Tremp, 1990. Holds a BSc in Physics from the Autonomous University of Barcelona, and a MSc in Renewable Energy and Sustainability from the University of Barcelona.

She has always been working in the wind sector developing and implementing SCADA data analyses. In her previous jobs, she also stayed in a wind control room coordinating performance analysis functionalities. Since 2015, she works in AWS Truepower on the development and implementation of Plant Performance Services in the Consulting Services department. Her work is focused on operational wind plants data analysis in order to assess the health status and performance of wind turbines, premature detection of failures and O&M improvement.

Jesica Piñón – Narón, 1989. Holds a MSc in Physics from the University of Santiago de Compostela and in Meteorology from the University of Barcelona.

She has been working in the enhancement of Numerical Weather Prediction participating in several projects and papers regarding the evaluation and improvement of the Weather Research and Forecasting (WRF) model. Currently, she is working in AWS Truepower in the Consulting Services department, where she develops SCADA data analysis tools to perform automatic data mining in order to identify wind turbines under-performance issues and potential failures within the Plant Performance Services.

Sandra Florentino – Recife, 1977. Holds a Bachelor degree in Civil Engineering at the UFPE/Federal State of Pernambuco University, and is specialized in wind energy utilization by German Institutes Deutsche WindGuard GmbH and Institute für Solare Energieversorgungstechnik – ISET.

She started her graduate career as researcher at the Department of Science, Technology and the Environment of State of Pernambuco, in the field of Hydrological Engineering. Since 2006, she works with wind and solar energy. Currently she is Project Manager at AWS Truepower in Rio de Janeiro´s office.

Mrs. Florentino spent last 10 years working in the areas of projects assessment in the development stage, feasibility studies, and performance of operating wind farms. Brazilian Market is her focus, with experience on wind and solar energy auctions.

Itamar Lessa – Fortaleza, 1986. Holds a BSc in Aeronautics Engineering from Instituto Tecnológico de Aeronáutica - ITA with academical interchange in the École Nationale Supérieure de Mécanique et d'Aérotechnique - ISAE / ENSMA, France.

He started his graduate career as intern of the E-FAN Project from EADS Innovation Works, an electric airplane project in France in 2012. Since 2012, he has been working in Casa dos Ventos with wind resource assessment, wind mapping, micrositing, energy assessment and project management, PPAs / Brazilian Electricity Sector Analysis and plant performance assessments. Currently he is the Plant Performance Leader and started MSc in Electricity Brazilian Sector Planning in the Escola Politécnica da USP.

José Vidal – Barcelona, 1974. Holds a MSc in Physics from the University of Barcelona, and a degree in Leadership and Team Management from ESADE Business School.

He started his graduate career as researcher and associate professor at the Meteorology Department in the University of Barcelona, in the field of Numerical Weather Prediction. Since 2003, he has been working in AWS Truepower in several applications of Numerical Methods in Wind Resource Assessment, including forecasting, wind mapping and energy assessment. Currently he is the Manager of the Consulting Services for Europe and Latin America.

Mr. Vidal has been actively participating in several EU funded projects in diverse roles, including Work Package Leader. José was also member of TPWind Working Group in Resource Assessment and for several years has been part of the Scientific Committee in the EWEA Conference.